ST. CHARLES PARISH CANALS AND BAYOUS IN SEGMENT 0205
TMDL FOR BIOCHEMICAL OXYGEN-DEMANDING SUBSTANCES

SUBSEGMENT 020501

SURVEYED AUGUST 19-23, 2002

REVISED TMDL REPORT

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For:
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EXECUTIVE SUMMARY

This report presents the results of calibrated dissolved oxygen (DO) modeling and total maximum daily load (TMDL) calculations for subsegment 020501 (St. Charles Parish Canals and Bayous in Segment 0205). The primary waterbody in this subsegment is Main Canal. The modeling was conducted to establish a TMDL for biochemical oxygen-demanding pollutants for the Main Canal watershed. Main Canal is located in southern Louisiana in the Barataria basin near New Orleans and its watershed includes Avondale Gardens Canal and other minor tributaries. The size of subsegment 020501 is approximately 33.6 square miles. The primary land uses are wetland forest, urban (primarily residential subdivisions), and agriculture. No point source discharges were included in the model, but several small point source discharges within the subsegment were included in the TMDL.

Inputs for the calibration model were developed from data collected during the August 2002 intensive survey, data collected by the Louisiana Department of Environmental Quality (LDEQ) at one monitoring station in the watershed, the LDEQ Reference Stream Study, and NPDES permits and permit applications for each of the point source dischargers. A satisfactory calibration was achieved for the model. In those cases where the calibration was not as accurate, the difference was in the conservative direction. For the projection models, data were taken from current discharge permits, current applications, and ambient temperature records. The Louisiana TMDL Technical Procedures manual (dated 09/23/2003) has been followed in this study.

Modeling was limited to low flow scenarios for both the calibration and the projections since the constituent of concern was dissolved oxygen and the available data was limited to low flow conditions. The model used was LAQUAL, a modified version of QUAL-TX, which has been adapted to address specific needs of Louisiana waters.

Subsegment 020501 was listed as impaired on both the EPA 1999 Court Ordered 303(d) list for Louisiana and the LDEQ Final 2002 303(d) list. The subsegment was found to be not supporting its designated use of fish and wildlife propagation. Main Canal was subsequently scheduled for TMDL development with other listed waters in the Barataria basin. According to the 1999 Court Ordered 303(d) list, the suspected causes of impairment included organic enrichment / low DO and nutrients; and the suspected sources were minor industrial point sources, package plants (small flows), inflow and infiltration, urban runoff / storm sewers, petroleum activities, septic tanks, and industrial activity. This TMDL addresses the organic enrichment / low DO impairment and the nutrient impairment.

Based on the results of the projection modeling, meeting the water quality standard for DO of 5.0 mg/L will require man-made nonpoint sources to be reduced by 100% for both summer and winter and natural background sources will have to be reduced by 32% for summer and 2% for winter. The no load scenarios (i.e., no reduction in natural background sources) yielded minimum DO values of 3.8 mg/L for summer and 4.9 mg/L for winter. This suggests that the existing DO standard for Main Canal is definitely not appropriate for summer and may not be appropriate for winter.

Nonpoint source load calculations and TMDL calculations were performed using LDEQ's standard TMDL spreadsheet. This spreadsheet calculates wasteload allocations (WLAs) for point sources, load allocations (LAs) for man-made nonpoint sources and natural nonpoint sources, and incorporates an explicit margin of safety (MOS). For this TMDL, the explicit MOS was set to 20% of the sum of the man-made nonpoint sources and the point sources. This MOS accounts for future growth as well as lack of knowledge concerning the relationship between pollutant loads and water quality. The explicit MOS is provided in addition to the implicit MOS, which is created by conservative assumptions in the modeling. A summary of the TMDL is provided in Table ES.1.

Table ES.1. TMDL for Main Canal (Sum of CBODu, NBODu, and SOD).

	Summer (May-Oct)		**Winter (Nov-Apr)**	
	Reduction	**Load (kg/day)**	**Reduction**	**Load (kg/day)**
Point Source WLA	0%	268	0%	268
Point Source Reserve MOS (20%)		67		67
Natural Nonpoint Source LA	32%	287	2%	389
Natural Nonpoint Source MOS (0%)		0		0
Man-made Nonpoint Source LA	100%	0	100%	0
Man-made Nonpoint Source MOS (20%)		0		0
TMDL	--	622	--	724

This subsegment was listed as impaired due to nutrients as well as organic enrichment / low DO. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants. LDEQ's position, as stated in the declaratory ruling issued by Dale Givens regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the dissolved oxygen criterion is supported, nutrients are also controlled and limited. The implementation of this TMDL through wastewater discharge permits and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources.

LDEQ will work with other agencies such as local Soil Conservation Districts to implement nonpoint source best management practices in the watershed through the 319 programs. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a four-year cycle. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the four-year cycle. Sampling is conducted on a monthly basis to yield approximately 12 samples per site each year the site is monitored. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, approximately one half of the state's waters are newly assessed for 305(b) and 303(d) listing purposes for each biennial cycle with sampling occurring statewide each year. The four-year cycle follows an initial five-year rotation which covered all basins in the state according to the TMDL priorities. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACKNOWLEDGMENTS

This TMDL was developed by FTN Associates, Ltd. with assistance from numerous LDEQ personnel, as well as several other people. The LDEQ project manager was Emelise Cormier and the FTN project manager was Philip Massirer. The guidance and assistance from Ms. Cormier throughout this project was extremely valuable. Other LDEQ personnel that provided valuable guidance at various times were Dick Duerr and Marian Aguillard.

Several field reconnaissance trips were made by LDEQ watershed survey personnel. A reconnaissance survey was performed by Philip Massirer of FTN, Dick Duerr of LDEQ, and several LDEQ watershed survey personnel.

The intensive survey was performed by LDEQ watershed survey personnel and the laboratory analyses of water samples were performed by LDEQ laboratory personnel. Initial compilation of some of the field data was done by LDEQ watershed survey personnel.

Operational records and other information for the Lake Cataouatche pump stations and Bayou Segnette pump stations were provided by Jefferson Parish Department of Engineering personnel.

The field data analysis, water quality modeling, TMDL calculations, and preparation of the report were performed by several FTN personnel including Richard Bennett and Philip Massirer.

ABBREVIATIONS

BMP	best management practice
BOD	biochemical oxygen demand
CBODu	ultimate carbonaceous biochemical oxygen demand
CFR	Code of Federal Register
cfs	cubic feet per second
DO	dissolved oxygen
EPA	Environmental Protection Agency
FTN	FTN Associates, Ltd.
ft/sec	feet per second
$g/m^2/day$	grams per square meter per day
kg/day	kilograms per day
km	kilometer
LA	load allocation
LAC	Louisiana Administrative Code
lbs/day	pounds per day
LC	loading capacity
LDEQ	Louisiana Department of Environmental Quality
LTP	Louisiana TMDL Technical Procedures Manual
MGD	million gallons per day
NBODu	ultimate nitrogenous biochemical oxygen demand
NCM	nonconservative material
NPDES	National Pollutant Discharge Elimination System
mg/L	milligrams per liter
TMDL	total maximum daily load
USGS	United States Geological Survey
WLA	wasteload allocation

1. Introduction

This report presents a total maximum daily load (TMDL) for biochemical oxygen demanding substances for subsegment 020501 (St. Charles Parish Canals and Bayous in Segment 0205). The primary waterbody in this subsegment is Main Canal. This subsegment was listed as impaired on both the 1999 Court Ordered 303(d) List for Louisiana (EPA 1999) and the Louisiana Department of Environmental Quality (LDEQ) Final 2002 303(d) List (LDEQ 2003a). On both of these 303(d) lists, organic enrichment/low dissolved oxygen (DO) and nutrients were cited as suspected causes of impairment. Therefore, development of a TMDL for biochemical oxygen demanding substances was required. A calibrated water quality model was developed and projections were simulated to quantify the load reductions which would be necessary in order for this subsegment to comply with established water quality standards and criteria. The TMDL in this report was developed in accordance with the LDEQ TMDL Technical Procedures Manual (known as the "LTP") (LDEQ 2003b) as well as federal requirements in Section 303(d) of the Federal Clean Water Act and the Environmental Protection Agency's (EPA) regulations in 40 CFR 130.7.

2. Study Area Description

2.1 General Information

Subsegment 020501 is located in southern Louisiana in the Barataria Basin southwest of New Orleans (see Figure A.1 in Appendix A). The waterbodies of interest in this subsegment are two manmade drainage canals named Main Canal and Avondale Gardens Canal. The northern boundary of this subsegment is formed by the levee along the south side of the Mississippi River, while the southern boundary of the subsegment is formed by another levee. Because much of this subsegment is below sea level, the levee on the south side prevents water from Lake Cataouatche and the surrounding marshes from inundating the land in this subsegment. Runoff from precipitation within this subsegment is pumped over the levee and out of the subsegment at two locations: the Lake Cataouatche pump stations and the Bayou Segnette pump station.

Most of the runoff is pumped out of the subsegment at the Lake Cataouatche pump stations, which are located along the southwestern edge of the subsegment (see Figure A.1). There are two pump stations at this location. A summary of information for the pump stations is shown in Table 2.1. Lake Cataouatche Pump Station No. 1 takes water from Main Canal and pumps it over the levee, while Lake Cataouatche Pump Station No. 2 takes water from the Inner Cataouatche Canal and pumps it over the levee. Main Canal is connected to the Inner Cataouatche Canal through a "bypass" that consists of three large gated pipes approximately 5 feet in diameter. Figure A.2 shows an aerial view of these two pump stations and the bypass. When water is being pumped out of the Inner Cataouatche Canal (i.e., when Lake Cataouatche Pump Station No. 2 is operating), the drawdown of the water in the Inner Cataouatche Canal will normally cause some of the water in Main Canal to flow through the bypass and into the Inner Cataouatche Canal. The Inner Cataouatche Canal extends along most of the southern edge of this subsegment.

Table 2.1. Information for pumping stations in subsegment 020501.

Name of pumping station	Pumps water from:	Pumps water to:	No. of pumps	Total capacity
Lake Cataouatche No. 1	Main Canal (southwestern end)	Outer Cataouatche Canal	2	500 cfs
Lake Cataouatche No. 2	Inner Cataouatche Canal	Outer Cataouatche Canal	2	600 cfs
Bayou Segnette	Main Canal (eastern end)	Bayou Segnette	6	936 cfs

The other location where water is pumped out of this subsegment is the Bayou Segnette pump station, which is located on the eastern edge of the subsegment (see Figure A.1). This pump station takes water from the eastern end of Main Canal and pumps it into Bayou Segnette. This pump station does not operate as often as the Lake Cataouatche pump stations.

All three of these pumping stations are operated for the purpose of keeping water levels in the subsegment from getting too high. Therefore, the pumps operate intermittently as needed. Usually the only time that multiple pump stations are operated simultaneously is during high water conditions from large storms. All three of these pumping stations are operated by Jefferson Parish.

Subsegment 020501 covers approximately 33.6 square miles. The primary land uses are wetland forest, urban (primarily residential subdivisions), and agriculture. Land use data for this subsegment are summarized in Table 2.2 and shown spatially on Figure A.3 (in Appendix A).

Table 2.2. Land use for subsegment 020501.

Land Use Type	Percent of Total Area
Fresh Marsh	11.0%
Wetland Forest Deciduous	45.3%
Upland Forest Deciduous	0.1%
Upland Forest Mixed	2.3%
Wetland Scrub/Shrub Deciduous	2.8%
Upland Scrub/Shrub Mixed	0.0%
Agriculture/Cropland/Grassland	16.1%
Vegetated Urban	19.0%
Nonvegetated Urban	0.0%
Wetland Barren	0.0%
Upland Barren	1.2%
Water	2.2%
TOTAL	100.0%

2.2 Water Quality Standards

The designated uses and numeric water quality standards for subsegment 020501 are listed below in Table 2.3. This subsegment has a year round DO standard of 5.0 mg/L.

Table 2.3. Water quality numeral criteria and designated uses (LDEQ 2003c).

Subsegment Number	020501
Subsegment Name	St. Charles Parish Canals and Bayous in Segment 0205
Designated Uses	A, B, C
Criteria:	
DO	5.0 mg/L
Chloride	65 mg/L
Sulfate	50 mg/L
pH	6.0 – 8.5
Bacteria	see note 1 below
Temperature	32 °C
TDS	430 mg/L

USES: A – primary contact recreation; B – secondary contact recreation; C – propagation of fish and wildlife; D – drinking water supply; E – oyster propagation; F – agriculture; G – outstanding natural resource water; L – limited aquatic life and wildlife use.

Note 1 – 200 colonies / 100 mL maximum log mean and no more than 25% of samples exceeding 400 colonies / 100 mL for May through October; 1000 colonies / 100 mL maximum log mean and no more than 25% of samples exceeding 2000 colonies / 100 mL for November through April.

As specified in EPA's regulations at 40 CFR 130.7(b)(2), applicable water quality standards include antidegradation requirements. The LDEQ antidegradation policy (LAC 33: IX.1109.A) includes the following statements that are applicable to this TMDL: "No lowering of water quality will be allowed in waters where standards for the designated water uses are not currently being attained. ... The administrative authority will not approve any wastewater discharge or certify any activity for federal permit that would impair water quality or use of state waters." The TMDL in this report is consistent with the LDEQ antidegradation policy.

2.3 Point Sources

A total of five National Pollutant Discharge Elimination System (NPDES) permits were identified for point source discharges within subsegment 020501. Information for these point source discharges is shown in Table 2.4. This information was obtained by reviewing data from both the LDEQ point source database and from a point source database prepared for the Barataria and Terrebonne basins under contract to EPA Region 6. The locations of these facilities are shown on Figure A.4 (in Appendix A). None of these facilities discharges directly into the waterbodies of interest in this subsegment (Main Canal and Avondale Gardens Canal); therefore, no point sources were included in the model.

Table 2.4. Information for point source discharges in subsegment 020501.

File Number	Company	Facility	Facility Type	Location	Receiving Water	Expected flow (MGD)	Outfall	BOD5 (mg/L)	TSS (mg/L)	modeling comments
LA0093157	SOUTHERN RECOVERY MGMT INC	GREATER NEW ORLEANS LANDFILL	SANITARY LANDFILL	S. KENNER RD, .5 MI. N OF US HWY 90	DUSUAUS CANAL, SELLERS CANAL - B VERRET - LAKE CATAOUATCHE	--	001	avg 30, max 45	avg 90, max 135	not in model, but in TMDL
							002	avg 30, max 45	avg 90, max 135	not in model, but in TMDL
LA0099473	RIVER BIRCH INC	RIVER BIRCH LANDFILL	SANITARY LANDFILL	WAGGAMAN, NEAR; S KENNER RD, 0.5M N US90	SAULS CANAL - WAGGAMAN CANAL - OUTFALL CANAL - LAKE CATAOUATCHE	0.23+	001	avg 30, max 45	avg 30, max 45	not in model, but in TMDL
							002	avg 45	--	not in model, but in TMDL
LA0072214	BROWNING-FERRIS IND (BFI)	AREA NINETY LANDFILL, INC	SANITARY LANDFILL	AVONDALE, 5301 UNITED STATES, HWY 90W	INNER CATAOUATCHE DRAINAGE C – OUTER CATAOUATCHE DRAINAGE C - B VERRET - LAKE CATAOUATCHE	--	--	avg 30, max 45	avg 90, max 135	Not in model, but in TMDL
LA0059871	PAKTANK CORP	WESTWEGO TERMINAL	LIQUID BULK TERMINAL STORMWATE	BRIDGE CITY 106 BRIDGE CITY AVE	BAYOU SEGNETTE (via canals and ditches within subsegment 020501)	--	--	--	max 90	Assumed to have negligible oxygen demand
LA0089052	JEFFERSON PH DEPT OF PUBLIC WORKS	JEFFERSON PH LDFL	LANDFILL	KENNER 5800 HWY 90 W	WAGGAMAN CANAL - OUTFALL CANAL - LAKE CATAOUATCHE	--	--	avg 30, max 45	avg 90, max 135	not in model, but in TMDL

2.4 Nonpoint Sources

Suspected nonpoint sources for subsegment 020501 have been listed in the 1999 Court Ordered 303(d) List for Louisiana (EPA 1999). These sources include urban runoff / storm sewers, inflow and infiltration, septic tanks, petroleum activities, and industrial. Based on LDEQ's experience in the Barataria basin, it is suspected that there is considerable nonpoint oxygen demand in this subsegment that is natural (i.e., not induced by human activities).

2.5 Water Quality Conditions/Assessment

As mentioned in Section 1, this subsegment was listed as impaired by both EPA and LDEQ due to organic enrichment / low DO and nutrients. The 303(d) listing is shown below in Table 2.5. The water quality data that LDEQ used to assess this subsegment and include it on the 303(d) list were ambient monitoring data collected at LDEQ station 0904 (Main Canal south of Waggaman, Louisiana). The location of this monitoring station is shown on Figure A.1. Data were collected at this station at approximately monthly intervals from January 2000 through December 2000. As shown in Table 2.6, ten of the twelve DO measurements (83%) were below the water quality standard of 5.0 mg/L.

Table 2.5. 303(d) listing for subsegment 020501.

Subsegment	**Description**	**Suspected sources**	**Suspected causes**	**Priority ranking (1=highest)**
020501	St. Charles Parish Canals and Bayous in segment 0205	Minor industrial point sources, Package plants (small flows), Inflow and infiltration, Urban runoff/Storm sewers, Petroleum activities, Septic tanks, Industrial	Organic enrichment/low DO, Pathogen indicators, Oil & Grease, Nutrients, Metals	3

Table 2.6. DO data for LDEQ station 0904 (Main Canal).

Date	**Time**	**DO (mg/L)**	**Meets standard?**
1/25/00	10:10	6.75	Yes
2/22/00	09:40	4.53	No
3/28/00	09:35	1.75	No
4/25/00	09:34	0.84	No
5/23/00	09:52	1.61	No
6/27/00	09:59	1.16	No
7/25/00	09:40	0.77	No
8/22/00	10:00	1.49	No
9/19/00	10:00	0.23	No
10/17/00	09:18	0.78	No
11/14/00	09:20	3.67	No
12/19/00	08:46	5.70	Yes

2.6 Previous Studies and Data

No previous water quality studies have been identified for subsegment 020501. There are no US Geological Survey (USGS) or Corps of Engineers stage gages or flow gages in the subsegment. The only historical water quality data that are known to exist are the LDEQ data mentioned in Section 2.5.

3. Field Survey

An intensive field survey was conducted by LDEQ personnel on Main Canal and Avondale Gardens Canal during the week of August 19-23, 2002. The purpose of this survey was to gather information about the subsegment and collect data that would be needed to set up and calibrate a water quality model. The field data that were collected included water quality samples and in situ measurements, continuous in situ monitoring, cross sections, velocity measurements with drogues, and a dye study for time of travel and dispersion. Continuous in situ monitoring data (temperature, DO, pH, and specific conductivity) were collected from August 19 to August 21. Water quality samples and associated in situ data were taken on August 20. A map and descriptions of the field data collection sites are included in Appendix B1.

3.1 Water Quality Sampling and In Situ Data

The water quality sampling data and the in situ data collected with the water quality samples are shown in Table B2.1 (in Appendix B2). Only three of the eight stations had DO readings above the water quality standard of 5.0 mg/L. Table B2.2 shows (also in Appendix B2) shows a comparison of data collected at MC-3 during the survey with LDEQ historical data collected during the summer of 2000 at station 0904 (same location as MC-3). Although TOC and TKN were slightly lower during the survey than during the summer of 2000, this comparison shows that in general, the survey data appear to be representative of summer conditions in Main Canal.

3.2 Continuous Monitoring Data

Figures B3.1 through B3.30 (in Appendix B3) show plots of the continuous in situ data collected during the survey. Some of the stations showed significant diurnal fluctuations of temperature, DO, and pH. The diurnal fluctuations of DO ranged from about 3 mg/L at MC-4 to about 8 mg/L at MC-1 and AGC-2. DO percent saturation levels exceeded 100% during the afternoon at all of the continuous monitoring locations except MC-3 and MC-4. Diurnal fluctuations of pH were small at MC-3 and MC-4, but the pH at AGC-2 fluctuated from 7.4 su to 8.4 su. The large DO fluctuations with supersaturated values indicate high algal productivity at some of the stations. The stations with the lowest algal productivity appeared to be MC-3 and MC-4. The continuous conductivity data showed some variability, but there were no obvious explanations for the variations. For example, the conductivity at MC-1 increased from about 660 µmhos to 1000 µmhos over a period of 40 hours, but the data at the other stations did not reflect that pattern. Continuous water level data were also measured, but did not show any significant diurnal luctuations because this system is not tidally influenced (since it is cut off from the Gulf by levees).

3.3 BOD Time Series Analyses

Results of 60-day BOD time series analyses are shown in Appendix B4. For each sample, values of cumulative oxygen demand and NO2+NO3 concentration were obtained at selected intervals over a period of about 60 days. These data were entered into an LDEQ spreadsheet called GSBOD, which contains algorithms for fitting first order curves to the data to calculate values of ultimate carbonaceous biochemical oxygen demand (CBODu), ultimate nitrogenous biochemical oxygen demand (NBODu), decay rates for both CBODu and NBODu, and lag times for both CBODu and NBODu. The results of these analyses are shown in Appendix B4.

3.4 Cross Section Data

Cross sections were measured at eight locations along Main Canal and four locations on Avondale Gardens Canal. These cross section data are shown in Appendix B5.

3.5 Drogue Measurements and Dye Study

Table B6.1 (in Appendix B6) shows velocity measurements made at each sampling site using drogues. The survey crew reported that the water at most locations appeared to be sloshing back and forth due to wind. They considered the drogue velocity at AGC-1 to be the only one that represented net advective flow.

A dye study was also conducted to measure velocity in Main Canal. A slug of dye was injected in Main Canal near MC-1 and automatic samplers were set up to measure dye concentrations at MC-6 and MC-7. Appendix B6 contains time of travel calculations (Tables B6.2 and B6.3) as well as plots of dye concentration versus time at these two locations (Figures B6.1 and B6.2). The average velocities calculated between the injection location and the sampling locations were both low (0.04 ft/sec for MC-6 and 0.02 ft/sec for MC-7). Because the dye cloud did not completely pass MC-7 within the sampling period, the actual average velocity between MC-1 and MC-7 is lower than the calculated value (0.02 ft/sec). The dye measurements at MC-6 appear to represent short term movement of water, while the dye measurements at MC-7 show that the net advection over a longer period of time was very small.

3.6 Pump Station Operational Data

Operational records for the pumping stations prior to and during the survey were provided by Jefferson Parish personnel. The Bayou Segnette pumping station did not operate during the survey or during the week prior to the survey. The Lake Cataouatche pump stations operated at least several hours every day between August 13 and August 20 (the day of the water quality sampling), except August 17 and 18. The pumping operations during August 19-20 are shown on Figure B6.3 (in Appendix B6). Except for one 5-minute period on August 19, all of the water pumped during August 19-20 was from the Inner Cataouatche Canal (rather than directly from Main Canal).

4. Documentation of Calibration Model

4.1 Program Description

"Simulation models are used extensively in water quality planning and pollution control. Models are applied to answer a variety of questions, support watershed planning and analysis and develop total maximum daily loads (TMDLs). ... Receiving water models simulate the movement and transformation of pollutants through lakes, streams, rivers, estuaries, or near shore ocean areas. ... Receiving water models are used to examine the interactions between loadings and response, evaluate loading capacities (LCs), and test various loading scenarios. ... A fundamental concept for the analysis of receiving waterbody response to point and nonpoint source inputs is the principle of mass balance (or continuity). Receiving water models typically develop a mass balance for one or more constituents, taking into account three factors: transport through the system, reactions within the system, and inputs into the system." (EPA841-B-97-006, pp. 1-30)

The model used for this TMDL was LA-QUAL, a steady-state one-dimensional water quality model. LA-QUAL has the mechanisms for incorporating hydraulic characteristics of Louisiana waterbodies and was particularly suitable for use in modeling Main Canal. LA-QUAL history dates back to the QUAL-I model developed by the Texas Water Development Board with Frank D. Masch & Associates in 1970 and 1971. William A. White wrote the original code.

In June, 1972, EPA awarded Water Resources Engineers, Inc. (now Camp Dresser & McKee) a contract to modify QUAL-I for application to the Chattahoochee-Flint River, the Upper Mississippi River, the Iowa-Cedar River, and the Santee River. The modified version of QUAL-I was known as QUAL-II.

Over the next three years, several versions of the model evolved in response to specific client needs. In March, 1976, the Southeast Michigan Council of Governments (SEMCOG) contracted with Water Resources Engineers, Inc. to make further modifications and to combine the best features of the existing versions of QUAL-II into a single model. That became known as the QUAL-II/SEMCOG version.

Between 1978 and 1984, Bruce L. Wiland with the Texas Department of Water Resources modified QUAL-II for application to the Houston Ship Channel estuarine system. Numerous modifications were made to enable modeling this very large and complex system including the addition of tidal dispersion, lower boundary conditions, nitrification inhibition, sensitivity analysis capability, branching tributaries, and various input/output changes. This model became known as QUAL-TX and was subsequently applied to streams throughout the State of Texas.

In 1999, LDEQ and Wiland Consulting, Inc. developed LA-QUAL based on QUAL-TX Version 3.4. The program was converted from a DOS-based program to a Windows-based program with a graphical interface and enhanced graphic output. Other program modifications specific to the needs of Louisiana and the LDEQ were also made. LA-QUAL is a user-oriented model and is intended to provide the basis for evaluating total maximum daily loads in the State of Louisiana.

The development of a TMDL for dissolved oxygen generally occurs in 3 stages. Stage 1 encompasses the data collection activities. These activities may include gathering such information as stream cross-sections, stream flow, stream water chemistry, stream temperature and dissolved oxygen and various locations on the stream, location of the stream centerline and the boundaries of the watershed which drains into the stream, and other physical and chemical factors which are associated with the stream. Additional data gathering activities include gathering all available information on each facility which discharges pollutants in to the stream, gathering all available stream water quality chemistry and flow data from other agencies and groups, gathering population statistics for the watershed to assist in developing projections of future loadings to the water body, land use and crop rotation data where available, and any other information which may have some bearing on the quality of the waters within the watershed. During Stage 1, any data available from reference or least impacted streams which can be used to gauge the relative health of the watershed is also collected.

Stage 2 involves organizing all of this data into one or more useable forms from which the input data required by the model can be obtained or derived. Water quality samples, field measurements, and historical data must be analyzed and statistically evaluated in order to determine a set of conditions which have actually been measured in the watershed. The findings are then input to the model. Best professional judgment is used to determine initial estimates for parameters which were not or could not be measured in the field. These estimated variables are adjusted in sequential runs of the model until the model reproduces the field conditions which were measured. In other words, the model produces a value of the dissolved oxygen, temperature, or other parameter which matches the measured value within an acceptable margin of error at the locations along the stream where the measurements were actually made. When this happens, the model is said to be calibrated to the actual stream conditions. At this point, the model should confirm that there is an impairment and give some indications of the causes of the impairment. If a second set of measurements is available for slightly different conditions, the calibrated model is run with these conditions to see if the calibration holds for both sets of data. When this happens, the model is said to be verified.

Stage 3 covers the projection modeling which results in the TMDL. The critical conditions of flow and temperature are determined for the waterbody and the maximum pollutant discharge conditions from the point sources are determined. These conditions are then substituted into the model along with any related condition changes which are required to perform worst case scenario predictions. At this point, the loadings from the point and nonpoint sources (increased by an acceptable margin of safety) are run at various levels and distributions until the model output shows that dissolved oxygen criteria are achieved. It is critical that a balanced distribution of the point and nonpoint source loads be made in order to predict any success in future achievement of water quality standards. At the end of Stage 3, a TMDL is produced which shows the point source permit limits and the amount of reduction in man-made nonpoint source pollution which must be achieved to attain water quality standards. The man-made portion of the nonpoint source pollution is estimated from the difference between the calibration loads and the loads observed on reference or least impacted streams.

4.2 Input Data Documentation

Data collected during the August 2002 intensive survey (described in Section 3) were used to establish the input for the model calibration. This survey was conducted during a period of low flows and warm temperatures.

The flows in the model were determined based on dye study results, selected drogue measurements, and volumes of water pumped at the Lake Cataouatche pump stations. Flow calculations are discussed in Section 4.2.11. A simulation of conservative constituents (e.g., chloride and conductivity) was performed to check the flow balance as discussed in Section 4.3.1.

Field and laboratory water quality data were entered in a spreadsheet for ease of analysis. The Louisiana GSBOD program was applied to the BOD time series data in a separate spreadsheet as described in Section 3. The survey data were the primary source for the model input data for initial conditions, decay rates, and inflow water quality.

4.2.1 Model Schematics and Maps

A vector diagram of the modeled area is presented in Figure 4.1 and in Appendix C. The vector diagram shows the locations of survey stations, the reach design, the location of the modeled tributary, and the locations of inflows. Although water can be pumped out of Main Canal at either end, the model was set up with the downstream end at the Lake Cataouatche pump stations because those pump stations are operated more often than the Bayou Segnette pump station (i.e., more water leaves the subsegment through the Lake Cataouatche pump stations than through the Bayou Segnette pump station). The reach design is discussed in Section 4.2.5. Maps showing the entire subsegment are included in Appendix A.

4.2.2 Model Options, Data Type 2

Five constituents were modeled during the calibration process. These were chlorides, conductivity, dissolved oxygen (DO), CBODu, and NBODu. The chlorides and conductivity were included in the model for the purpose of checking the flow balance. NBODu was represented in the model as nonconservative material (NCM).

4.2.3 Program Constants, Data Type 3

Two program constants were specified in the model input. First, the hydraulic calculation method was specified as 2 rather than 1. Method 2 is the preferred method and allows the user to input widths and depths rather than velocities and depths. The other program constant that was specified was the NCM oxygen uptake rate, which was set to 1.0 mg of oxygen consumed per mg of NCM decayed.

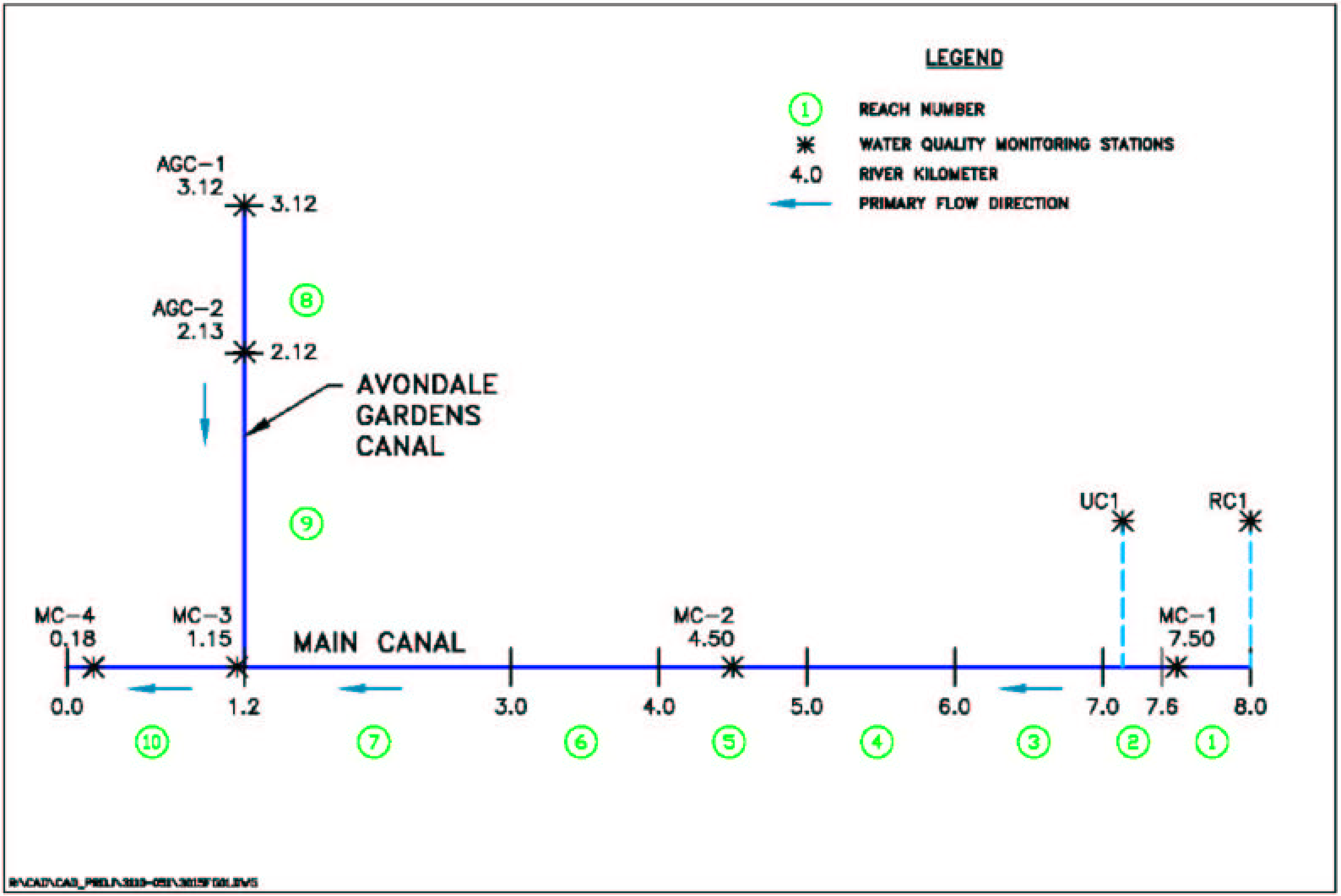

Figure 4.1. LA-QUAL Vector Diagram for Main Canal System

4.2.4 Temperature Correction of Kinetics, Data Type 4

The temperature values in the model are used to correct the rate coefficients in the source/sink terms for the other water quality variables. These coefficients are input at 20°C and are then corrected to the stream temperatures using the following equation:

$$X_T = X_{20} * Theta^{(T-20)}$$

where:

X_T = the value of the coefficient at the local temperature T in degrees Celsius
X_{20} = the value of the coefficient at the standard temperature (20 degrees Celsius)
Theta = an empirical constant for each reaction coefficient

In the absence of specified values for data type 4, the model uses default values. The default theta values include 1.047 for CBOD decay, 1.070 for nonconservative material (NBOD) decay, and 1.065 for SOD. All three of these default values were consistent with the LTP (LDEQ 2003b), so no values were explicitly specified in data type 4.

4.2.5 Reach Identification Data, Data Type 8

The model includes Main Canal starting near the east side of the subsegment (near the Bayou Segnette pump station) and extending to the southwest edge of the subsegment (at the Lake Cataouatche pump stations). The model also includes Avondale Gardens Canal from near Highway 90 to its confluence with Main Canal. No other branches were modeled. A vector diagram of the model is shown in Appendix C.

The system being modeled was divided into a total of 10 reaches based on changes in width and depth. The element size was approximately 0.10 km throughout the model. The widths and depths are discussed in Section 4.2.6.

4.2.6 Hydraulic Coefficients, Data Types 9 and 10

The hydraulics were specified in the model input for the LA-QUAL model using the power functions (width = a * Q^b + c and depth = d * Q^e + f). Values specified in the model for these power functions are shown in Table D.1 in Appendix D. Based on the low gradient of streams in this subsegment and hydraulic conditions during the intensive field survey, it was assumed that changes in the stream flow rate between the calibration and projection simulations would create only negligible changes in depths and widths. Therefore, the coefficients and exponents (a, b, d, and e) were set to zero and the constants (c and f) were set based on the widths and depths from measured cross sections. The cross section measured at MC-1 was not used because it was taken at a bridge where the section is not representative. Plots of modeled and observed depths and widths for Main Canal and Avondale Gardens Canal are shown in Appendix E.

Due to intermittent pumping and wind influences, the Main Canal system does have some dispersion (as shown from the dye study). However, the dispersion coefficients in data type 10 were not used for this model. This system is not tidally influenced because it is cut off from the Gulf by levees. Also, test simulations showed that adding dispersion up to 5 m^2/sec caused little change in the predicted water quality.

4.2.7 Initial Conditions, Data Type 11

The initial conditions were used to specify the temperature and salinity for each reach and reduce the number of iterations required by the model for constituents being simulated. The values required for this model were temperature, salinity, and DO by reach. The input values came from the survey station(s) located closest to the reach or from an average of samples taken from stations located within the reach. For DO, the initial values were set to the calibration targets. The model inputs and data sources for the initial conditions are shown in Table D.2 in Appendix D.

Although chlorophyll data were available from the intensive survey, chlorophyll values were not specified in the initial conditions because the effects of algae on DO were taken into account through the determination of calibration target values for DO (discussed in Section 4.3.2).

4.2.8 Reaeration Rates, Data Type 12

For reaeration, the Louisiana equation (option 15) was used because it was developed specifically for streams in Louisiana and it has been used successfully for other TMDLs in Louisiana. Also, the depths and velocities measured during the intensive survey were generally within the range of values for which the equation was developed (LDEQ 2003b). Based on the narrow width of the stream, wind-aided reaeration was not used for this system. The model inputs for reaeration are shown in Table D.3 in Appendix D.

4.2.9 SOD, Data Type 12

The SOD values were achieved through calibration and ranged from 0.10 g/m^2/day to 4.25 g/m^2/day in Main Canal, with the higher values near the confluence of Main Canal and Avondale Gardens Canal (reaches 6 and 7). The SOD values used in the model are shown in Table D.4 in Appendix D. Results of the water quality calibration are discussed in Section 4.3.2.

4.2.10 CBODu and NBODu Rates, Data Types 12 and 15

The CBODu and NBODu decay rates used in the model were based on values calculated by the LDEQ spreadsheet GSBOD for each station. The decay rate used for a reach was based on the measured decay rate (CBODu and NBODu) for the station in that reach. For reaches without a station in them, the decay rates were varied linearly. The decay rates are summarized in Table B4.1 in Appendix B. For both CBODu and NBODu, the variability in decay rates among the samples was not unusually large (for this type of analysis) and did not show a consistent spatial pattern.

CBODu and NBODu settling rates were not used in the model because there was no information suggesting that simulating CBODu or NBODu settling was necessary. There were no point source discharges or other inflows that are known to be high in particulate CBODu or NBODu. The effects of settled CBODu and NBODu on DO are already implicitly included in the SOD.

4.2.11 Flow Calculations

Average flows for the Main Canal system during the intensive field survey were difficult to quantify. The flow at each sampling station was estimated using velocities from drogue measurements and cross sectional areas, but these flow data did not follow a consistent spatial pattern. The inconsistency among drogue measurements was apparently caused by water sloshing back and forth due to wind and low flow conditions (i.e., not enough advective flow to create a steady current).

The general approach that was used for determining flows for the Main Canal system during the intensive field survey can be summarized in the following steps (calculations are shown in Appendix F):

1. Calculate the outflow from the system (through Lake Cataouatche pump stations)
2. Calculate the headwater inflows for Main Canal and Avondale Gardens Canal
3. Calculate the incremental inflow as the outflow minus the two headwater inflows

The outflow from the system was calculated based on the total amount of water pumped at the Lake Cataouatche pump stations during August 19-20. The day prior to sampling was included in the average because the flows at the upper end of Main Canal may be affected by pumping rates on the previous day (due to the lag time from one end of Main Canal to the other, which is a distance of approximately 5 miles). During August 19-20, nearly all of the pumping was from Lake Cataouatche pump station #2, which pumps water out of the Inner Cataouatche Canal. In other words, much of the water being pumped was coming from the Inner Cataouatche Canal rather than directly from Main Canal. Therefore, the total amount of water pumped out at the Lake Cataouatche pump stations was multiplied by the estimated fraction of the subsegment that drains into Main Canal.

The headwater inflow for Main Canal was calculated using the velocity from the dye study between MC-1 and MC-7 and the average of the cross sectional areas for MC-6 and MC-7. The headwater inflow for Avondale Gardens Canal was calculated using the drogue velocity and cross sectional area for AGC-1.

The remaining inflow to the system (the outflow minus the two headwater inflows) was represented in the model as incremental inflow. During the survey, there were no tributaries that were identified as having significant advective inflow to Main Canal. The incremental inflow was specified for all reaches in the model assuming a constant inflow per kilometer.

4.2.12 Incremental Inflow, Data Types 16, 17, and 18

The flow rates for incremental inflow were calculated as described in Section 4.2.11. The values used for model inputs for the incremental inflows are shown in Table D.5 in Appendix D.

Based on preliminary model results and review of the field data, none of the tributary or headwater stations were considered to be representative of incremental inflow for this system. Therefore, concentrations for incremental inflow were based upon best professional judgement and calibration.

For the conservative materials (conductivity and chloride), the incremental inflow concentrations were initially set based on measured values in the stream. Because the stream was somewhat a "non-flowing" system during the field survey, the measured values in the stream were thought to be representative of incremental inflow entering the stream. However, using these values in the model did not provide a good match between predicted and observed concentrations. Because there was considered to be more uncertainty in the incremental inflow concentrations than in the flow calculations, it was decided to adjust the incremental inflow concentrations to improve the match between predicted and observed values of chloride and conductivity.

For the other parameters (DO, CBODu, and NBODu), incremental inflow concentrations were set to values that were within or similar to the ranges of the measured values in the stream.

4.2.13 Nonpoint Source Loads, Data Type 19

Nonpoint source loads which were not associated with a flow are input into this part of the model. These loads can be most easily understood as resuspended load from the bottom sediments and are modeled as SOD, CBODu loads, and NBODu loads. These loads were used as calibration parameters and adjusted to get the model to match observed data. The values used for the model input data for nonpoint source loads are shown in Table D.4 in Appendix D.

4.2.14 Headwaters, Data Types 20, 21, and 22

Headwater inputs were specified for Main Canal and for Avondale Gardens Canal. The headwater flow rates were calculated as described in Section 4.2.11. The water quality for the headwaters was based on observed data at stations MC-1 and AGC-1. The values used for model inputs for the headwaters are shown in Table D.6 in Appendix D.

The DO values for the headwaters were based on estimated daily average DO values for MC-1 and AGC-1. Because continuous monitoring data were not available for AGC-1, the daily average DO at this station was estimated using continuous monitoring data at AGC-1. The ratio of the instantaneous DO to daily average DO at AGC-2 was calculated for 15 minute intervals throughout the day. Then the instantaneous DO at AGC-1 was divided by the ratio corresponding to the measurement time at AGC-1 (see calculations in Appendix G).

4.2.15 Wasteloads, Data Types 24 and 25

No wasteloads were specified in the model because there were no tributary inflows or point sources being simulated.

4.3 Model Discussion and Results

4.3.1 Simulation of Chloride and Conductivity

Before calibrating the water quality, the model predictions for chloride and conductivity were examined as an attempt to evaluate the flow balance. Because there was large uncertainty about incremental inflow water quality, the flow balance could not be confirmed using the chloride and simulations. As discussed in Section 4.2.12, the chloride and conductivity concentrations for the incremental inflow were adjusted during calibration. Plots of predicted and observed chloride and conductivity for Main Canal and Avondale Gardens Canal are shown in Appendix H.

For Main Canal, the observed values of chloride and conductivity generally increase from upstream to downstream, indicating that incremental inflow concentrations are higher than headwater concentrations. For Avondale Gardens Canal, the observed conductivity and chloride values were lower at AGC-2 than at AGC-1; thus, the incremental inflow concentrations of chloride and conductivity are lower than the headwater concentrations.

4.3.2 Water Quality Calibration Results

Plots of predicted and observed values of CBODu, NBODu, and DO for Main Canal and Avondale Gardens Canal are shown in Appendix I. Plots of predicted and observed DO are also shown in Figures 4.2 and 4.3. A printout of the tabular model output is included in Appendix J.

The DO calibration targets were set to 1 mg/L above the minimum DO from continuous monitoring data collected on the day of the water quality sampling (August 20). Calibrating to 1 mg/L above the minimum was done based on recent LDEQ policy for streams with diurnal DO fluctuations between 2 mg/L and 9 mg/L.

The calibration results for NBODu, CBODu, and DO were good for both Main Canal and Avondale Gardens Canal. To match the DO calibration target at MC-3, an unusually high SOD value (4.25 g/m^2/day) had to be used in reach 7. However, reach 7 includes the area just upstream of the confluence of Main Canal and Avondale Gardens Canal where large amounts of debris were observed during the reconnaissance.

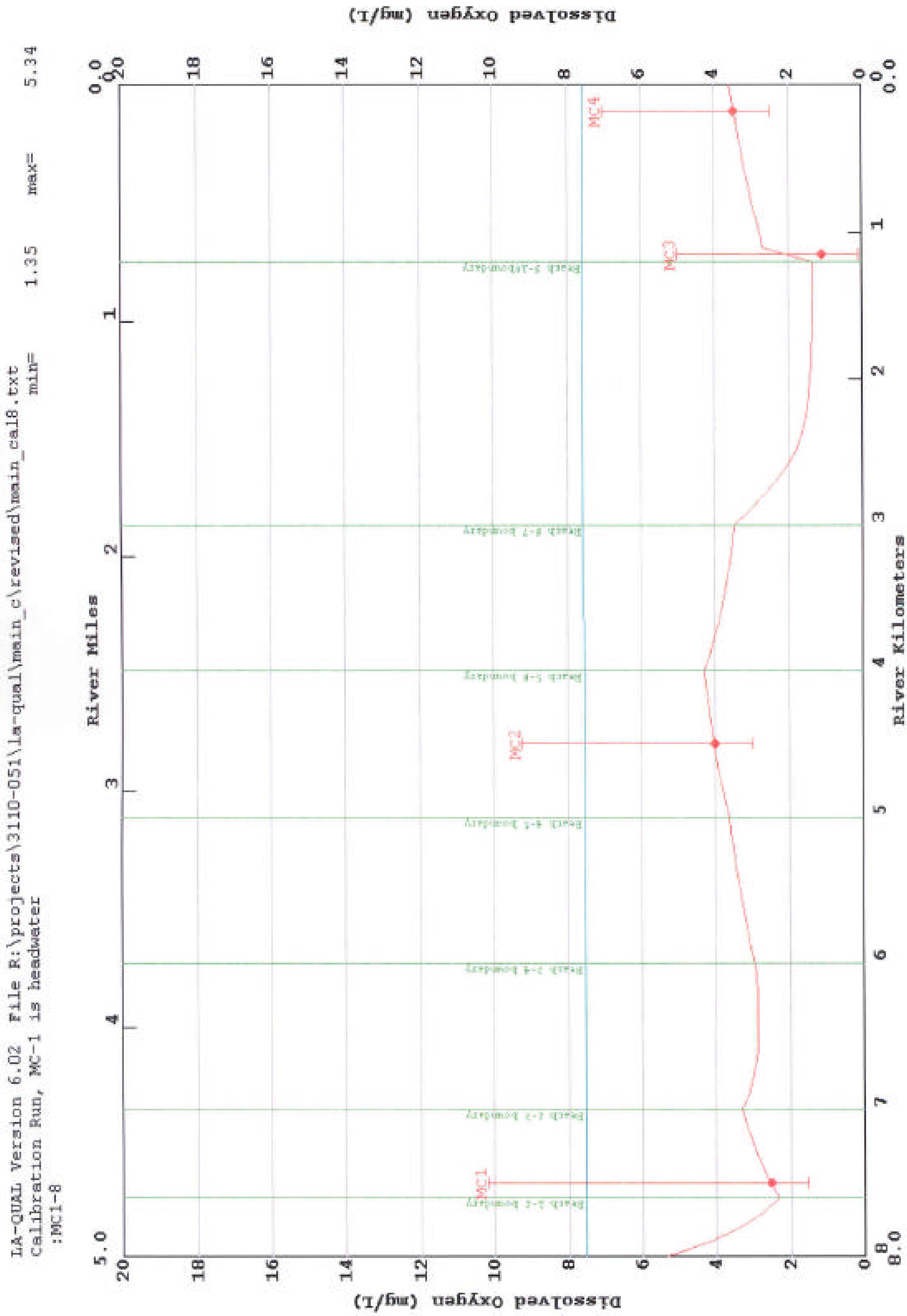

Figure 4.2. Predicted and observed DO for Main Canal calibration.

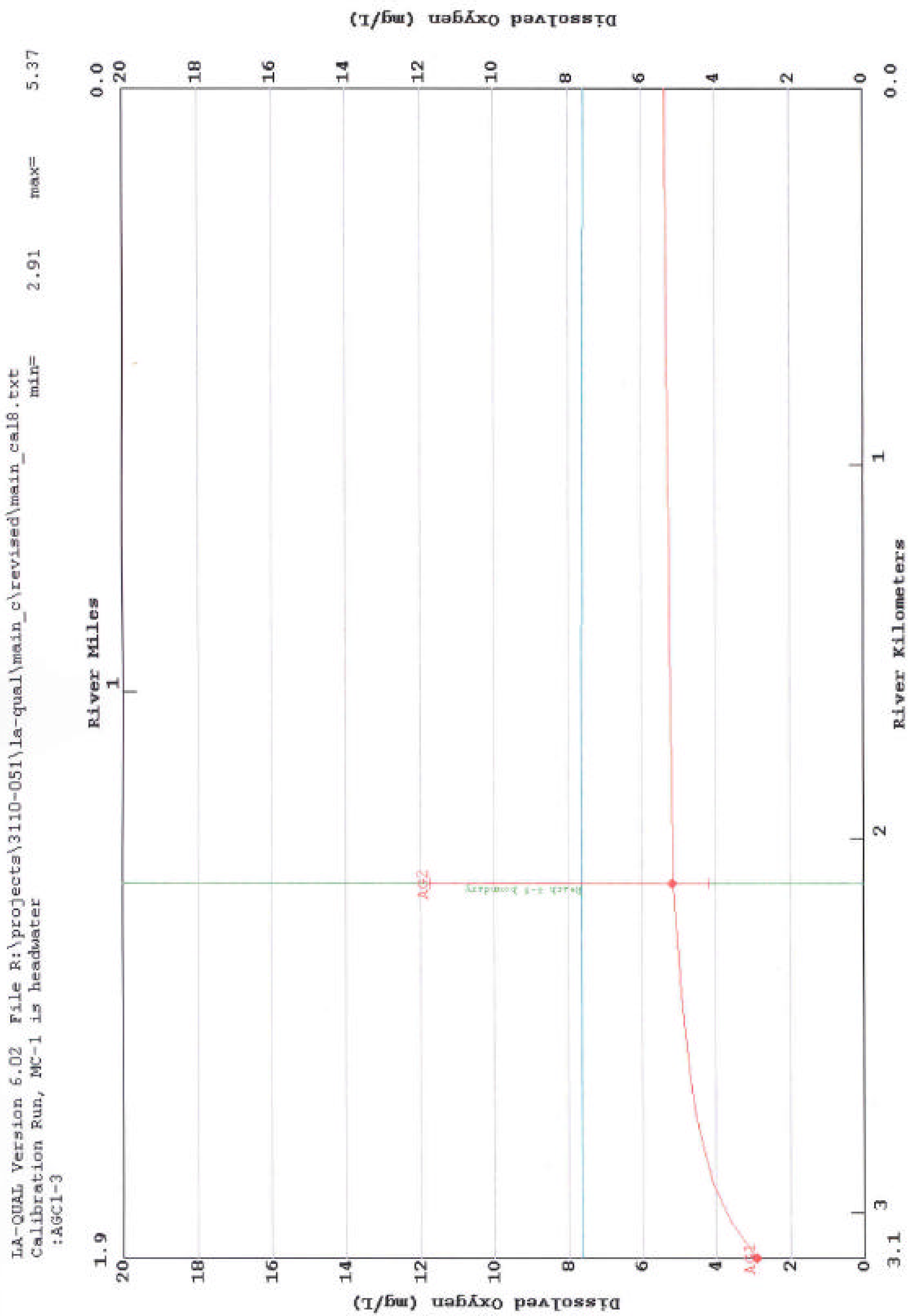

Figure 4.3. Predicted and observed DO for Avondale Gardens Canal calibration.

5. Water Quality Projections

Since the calibrated model indicated that the DO criterion was not being met in Main Canal, no load scenarios were performed in addition to the traditional summer and winter projections.

5.1 Critical Conditions, Seasonality and Margin of Safety

The Clean Water Act requires the consideration of the seasonal variation of the conditions affecting the constituent of concern, and the inclusion of a margin of safety (MOS) in the development of a TMDL.

Critical conditions for dissolved oxygen were determined for Main Canal using long term water quality data from Bayou Segnette and short term water quality data from Main Canal from the LDEQ Ambient Monitoring Network. The only temperature data within the Main Canal subsegment were the 12 monthly values for station 0904 ("Main Canal South of Waggaman, LA"). The closest LDEQ station with long term temperature data was station 0296 ("Bayou Segnette near Westwego, LA"). Seasonal 90th percentile temperatures were calculated using the Bayou Segnette data and then adjusted based on differences between temperatures measured on the same days during 2000 in both Bayou Segnette and Main Canal. These calculations are shown in Appendix K.

Graphical and regression analysis techniques have been used by LDEQ historically to evaluate the temperature and dissolved oxygen data from the Ambient Monitoring Network and run-off determinations from the Louisiana Office of Climatology water budget. Since nonpoint loading is conveyed by run-off, this was a reasonable correlation to use. Temperature is strongly inversely proportional to dissolved oxygen and moderately inversely proportional to run-off. Dissolved oxygen and run-off are also moderately directly proportional. The analysis concluded that the critical conditions for stream dissolved oxygen concentrations were those of negligible nonpoint run-off and low stream flow combined with high stream temperature.

When the rainfall run-off (and non-point loading) and stream flow are high, turbulence is higher due to the higher flow and the temperature is lowered by the run-off. In addition, run-off coefficients are higher in cooler weather due to reduced evaporation and evapotranspiration, so that the high flow periods of the year tend to be the cooler periods. Reaeration rates and DO saturation are, of course, much higher when water temperatures are cooler, but BOD decay rates are much lower. For these reasons, periods of high loading are periods of higher reaeration and dissolved oxygen but not necessarily periods of high BOD decay.

This phenomenon is interpreted in TMDL modeling by assuming that nonpoint loading associated with flows into the stream are responsible for the benthic blanket which accumulates on the stream bottom and that the accumulated benthic blanket of the stream, expressed as SOD and/or resuspended BOD in the calibration model, has reached steady state or normal conditions over the long term and that short term additions to the blanket are off set by short term losses. This accumulated loading has its greatest impact on the stream during periods of higher temperature and lower flow. The manmade portion of the NPS loading is the difference between the calibration load and the reference stream load where the calibration load is higher. The only mechanism for changing this normal benthic blanket condition is to implement best management practices and reduce the amount of nonpoint source loading entering the stream and feeding the benthic blanket.

Critical season conditions were simulated in the dissolved oxygen TMDL projection modeling by using the default flows from the Louisiana Technical Procedures Manual (LTP), and the 90th percentile temperature. Incremental flow was assumed to be zero; model loading was from perennial tributaries, sediment oxygen demand, and resuspension of sediments.

In reality, the highest temperatures occur in July-August, the lowest stream flows occur in October-November, and the maximum nonpoint source loading occurs following a significant rainfall, i.e., high-flow conditions. The summer projection model is established as if all these conditions happened at the same time. The winter projection model accounts for the seasonal differences in flows and BMP efficiencies. Other conservative assumptions regarding rates and loadings are also made during the modeling process. In addition to the conservative measures, an explicit MOS of 20% was used for all man-made loads to account for future growth, safety, model uncertainty and data inadequacies.

5.2 Input Data Documentation

The values and sources of the input data used for the summer projection, summer no load, winter projection, and winter no load scenarios are shown in Appendix L. Except as mentioned below, the projection inputs were unchanged from the calibration.

5.2.1 Initial Conditions, Data Type 11

The initial temperatures were set to the 90th percentile temperature for each season in accordance with the LTP. The initial DO and salinity values were unchanged from the calibration.

5.2.2 SOD and Nonpoint Sources, Data Types 12 and 19

The nonpoint source values were calculated for each projection scenario using a load equivalent spreadsheet. An analysis was made of the calibration nonpoint source and SOD loads in terms of total loading in units of g O_2/m^2/day and compared to the reference stream loads in the same terms (which accounted for the width differences between the reference and the modeled streams). All of the calibration values were larger than reference stream values. The same spreadsheet also calculated load reductions for the headwaters.

LDEQ has collected and measured the CBOD and NBOD oxygen demand loading components for a number of years. These loads have been found in all streams including the non-impacted reference streams. It is LDEQ’s opinion that much of this loading is attributable to runoff loads which are flushed into the stream during runoff events, and subsequently settle to the bottom in the slow moving streams. These benthic loads decay and breakdown during the year, becoming easily resuspended into the water column during the low flow/high temperature season. This season has historically been identified as the critical dissolved oxygen season.

LDEQ simulates part of the nonpoint source oxygen demand loading as resuspended benthic load and SOD. The calibrated nonpoint loads (CBODu, NBODu, and SOD) are summed to produce the total calibrated benthic load. The total calibrated benthic load is then reduced by the total background benthic load (determined from LDEQ's reference stream research) to determine the total manmade benthic loading. The manmade portion is then reduced incrementally on a percentage basis to determine the necessary percentage reduction of manmade loading required to meet the water body's dissolved oxygen criteria. These reductions are applied uniformly to all reaches sharing similar hydrology and land uses.

Following the same protocol as the point source discharges, the total reduced manmade benthic load is adjusted for the margin of safety by dividing the value by one minus the margin of safety. This adjusted load is added back to the total background benthic value to obtain the total projection model benthic load. This total projection benthic load is then broken out into its components of SOD, resuspended CBOD, and resuspended NBOD by multiplying the total projection benthic load by the ratio of each calibrated component to the total calibrated benthic load.

LDEQ has found variations in the breakdown of the individual CBOD and NBOD components. While the total BOD is reliable, the carbonaceous and nitrogenous component allocation is subject to the type of test method. In the past, LDEQ used a method which suppressed the nitrogenous component to obtain the carbonaceous component value, which was then subtracted from the total measured BOD to determine the nitrogenous value. The suppressant in this method was only reliable for twenty days thus leading to the assumption that the majority of the carbonaceous loading was depleted within that period of time. The test results supported this assumption. Recently the suppressant started failing around day seven and the manufacturer of the suppressant will only guarantee its potency for a five day period. LDEQ felt a five day test would not adequately depict the water quality of streams and began a search for a new test method. The research found a new proposed method for testing long term BODs in Standard Methods.

This proposed method is a sixty day test which measures the incremental total BOD of the sample while at the same time measuring the increase in nitrite/nitrate in the sample. This increase in nitrite/nitrate allows LDEQ to calculate the incremental nitrogenous portion by multiplying the increase by 4.57 to determine the NBOD daily readings. These NBOD daily readings are then subtracted from the daily readings for total BOD to determine the CBOD daily values. A curve fit algorithm is then applied to the daily component readings to obtain the estimated ultimate values of each component as well as the decay rate and lag times of the first order equations.

LDEQ has implemented the new test method over the last several survey seasons. The results obtained using the new method showed that a portion of the CBOD first order equation does begin to level off prior to the twentieth day; however a secondary CBOD component begins to use dissolved oxygen sometime between day ten and day twenty-five. This secondary CBOD component was not being assessed as CBOD using the previous method but was being included in the NBOD load. Thus the CBOD and NBOD component loading used in the reference stream studies is not consistent with the results using the new proposed 60 day method and the individual values should not be used to determine background values for samples processed using the new test method. However, the sum of CBOD and NBOD should be about the same for both new and old test methods. For this reason, background values in this model are based on the sum of reference stream benthic loads.

LDEQ's reference stream data were examined to identify reference streams that might be applicable for estimating background loads for Main Canal. Although none of the reference streams is located in or near the Barataria basin, four reference streams were identified as having some characteristics (i.e., sediment type, depth, velocity) similar to Main Canal. The nonpoint source loads estimated by LDEQ for these four reference streams are shown in Table 5.1 below. Based on previous experience with DO TMDLs in Louisiana, the total nonpoint source loads for Saline Bayou and Beaucoup Bayou (3.9 to 4.0 g/m^2/day) seemed unreasonably high as estimates of background loading for Main Canal. Therefore, the background load for Main Canal and Avondale Gardens Canal was set to 2.0 g/m^2/day based on the estimated loads for Big Roaring Bayou and Indian Bayou.

Background concentrations of CBODu and NBODu in the headwaters were also estimated based on LDEQ's reference stream data. Concentrations of CBODu and NBODu in these four reference streams are shown in Table 5.1. The concentrations were lower for Saline Bayou than for the other three streams, which could be due to the fact that Saline Bayou had more flow than the other three streams. Because the Main Canal system has very little advective flow during critical conditions, the background concentrations for the Main Canal system were based on values for Big Roaring Bayou, Indian Bayou, and Beaucoup Bayou (all of which were not flowing during the surveys). Based on data for these three streams, a concentration of 9 mg/L of total BODu (i.e., sum of CBODu and NBODu) was selected as the background value. However, the LDEQ TMDL spreadsheet requires individual concentrations of CBODu and NBODu. Therefore, the background concentration of total BODu was divided between CBODu and NBODu based on the ratio of CBODu to NBODu for each inflow in the calibration. For Avondale Garden Canal, though, the calibration values of headwater CBODu and NBODu were used as background concentrations because their sum was less than 9 mg/L.

Table 5.1. Data from selected LDEQ reference streams (Smythe 1999).

	Big Roaring Bayou	Indian Bayou	Beaucoup Bayou	Saline Bayou Site 2-3
Sediment type	silt	silt	silt	silt
Velocity during survey (m/sec)	0.00	0.00	0.00	0.23
Depth during survey (m)	1.08	0.64	0.67	0.93
NPS CBODu load (g/m^2/day)	0.688	0.218	0.169	0.531
NPS NBODu load (g/m^2/day)	0.095	0.090	0.498	1.637
SOD at 20°C (g/m^2/day)	1.45	1.52	4.20	2.25
Temperature during survey (°C)	20.15	20.82	16.45	16.11
SOD at stream temp. (g/m^2/day)	1.46	1.60	3.36	1.76
Total NPS load (g/m^2/day)	2.24	1.91	4.03	3.93
CBODu concentration (mg/L)	3.48	2.94	2.72	1.60
NBODu concentration (mg/L)	5.41	7.26	5.80	3.70

5.2.3 Incremental Inflow, Data types 16, 17, and 18

The incremental inflows were set to zero to simulate critical low flow conditions (as discussed in section 5.1).

5.2.4 Headwaters, Data Types 20, 21, and 22

Since there were no USGS flow gages in this subsegment there were no published 7Q10 values to be used. Therefore, the flow rate for each headwater was set to 0.1 cfs (0.003 m^3/sec) for summer and 1.0 cfs (0.03 m^3/sec) for winter as specified in the LTP.

The 90th percentile temperatures were used for the headwaters. The DO for the two headwaters was set to 90% of saturation as specified in the LTP. Headwater concentrations of CBODu and NBODu were set based on background concentrations and percent reduction calculations in the spreadsheets discussed in Section 5.2.2.

5.3 Model Discussion and Results

5.3.1 No Load Scenarios

The summer and winter no load scenarios were run to predict DO concentrations with no man-made sources under critical conditions. Printouts of the spreadsheets with nonpoint source load calculations for these scenarios are presented in Appendix M. Graphs of the predicted DO and printouts of the tabular output are presented in Appendix N.

The minimum predicted DO values from the no load scenarios were 3.8 mg/L for summer and 4.9 mg/L for winter. In other words, these simulations showed that complete elimination of man-made sources would result in DO values well below the current standard during summer and slightly below the standard during winter. Based on these results, the current DO standard should definitely be reevaluated for summer and may need to be reevaluated for winter.

5.3.2 Summer and Winter Projections

The summer and winter projection simulations were run to determine the allowable loadings and percent reductions for the Main Canal system that would result in the existing DO standard being maintained. Printouts of the spreadsheets with nonpoint source load calculations for these scenarios are presented in Appendix O. Graphs of the predicted DO and printouts of the tabular output for these scenarios are presented in Appendix P. Graphs of the predicted DO are also shown in Figures 5.1 through 5.4.

As shown in Table 5.2, the load reductions that were required for the model to show the DO standard being met included both a complete elimination of man-made nonpoint sources plus some reduction of background nonpoint sources. For each scenario, a uniform percent reduction was applied to all reaches in the model because the hydrology and land uses appeared to be similar for all reaches.

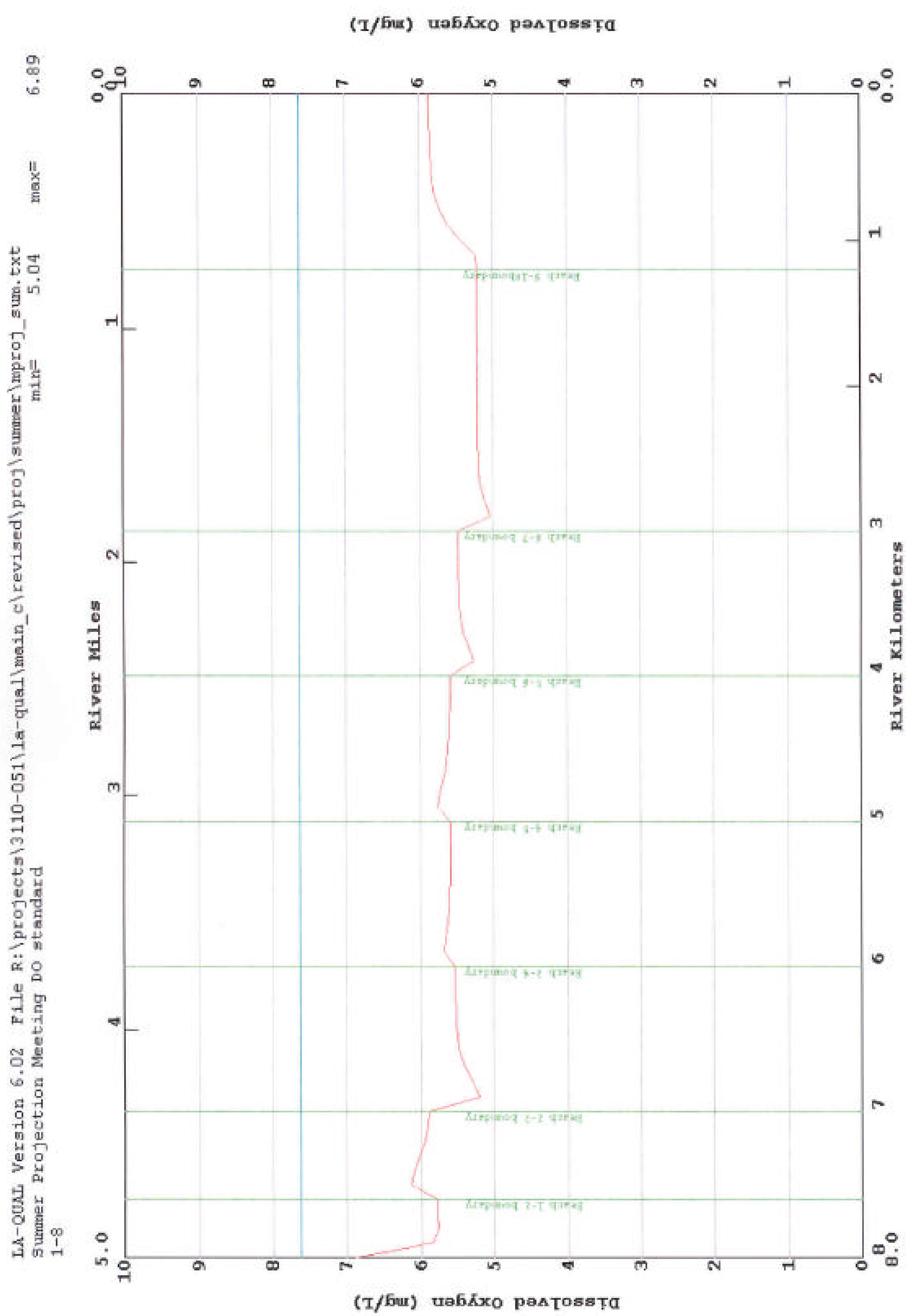

Figure 5.1. Predicted DO for Main Canal summer projection.

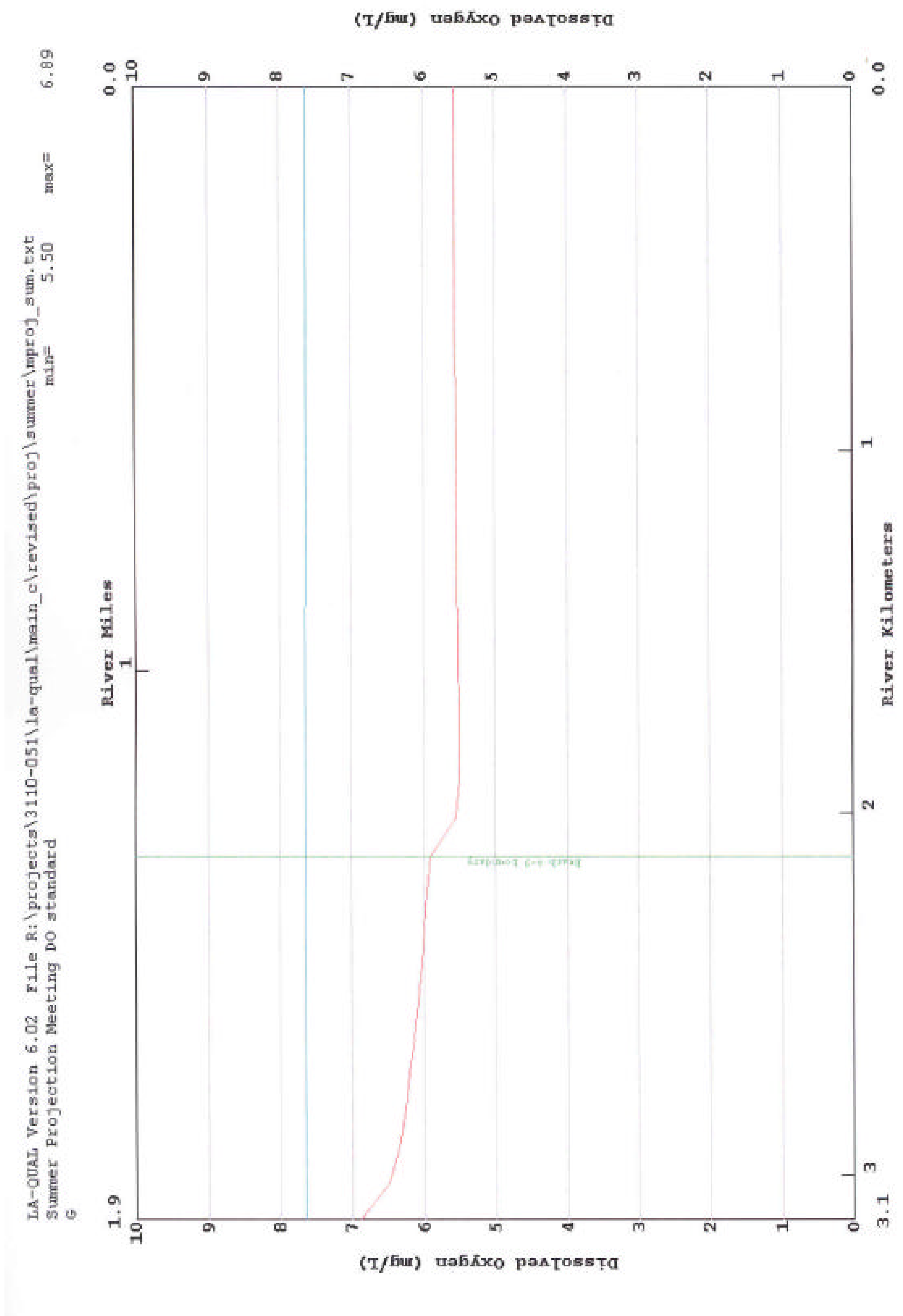

Figure 5.2. Predicted DO for Avondale Gardens Canal summer projection.

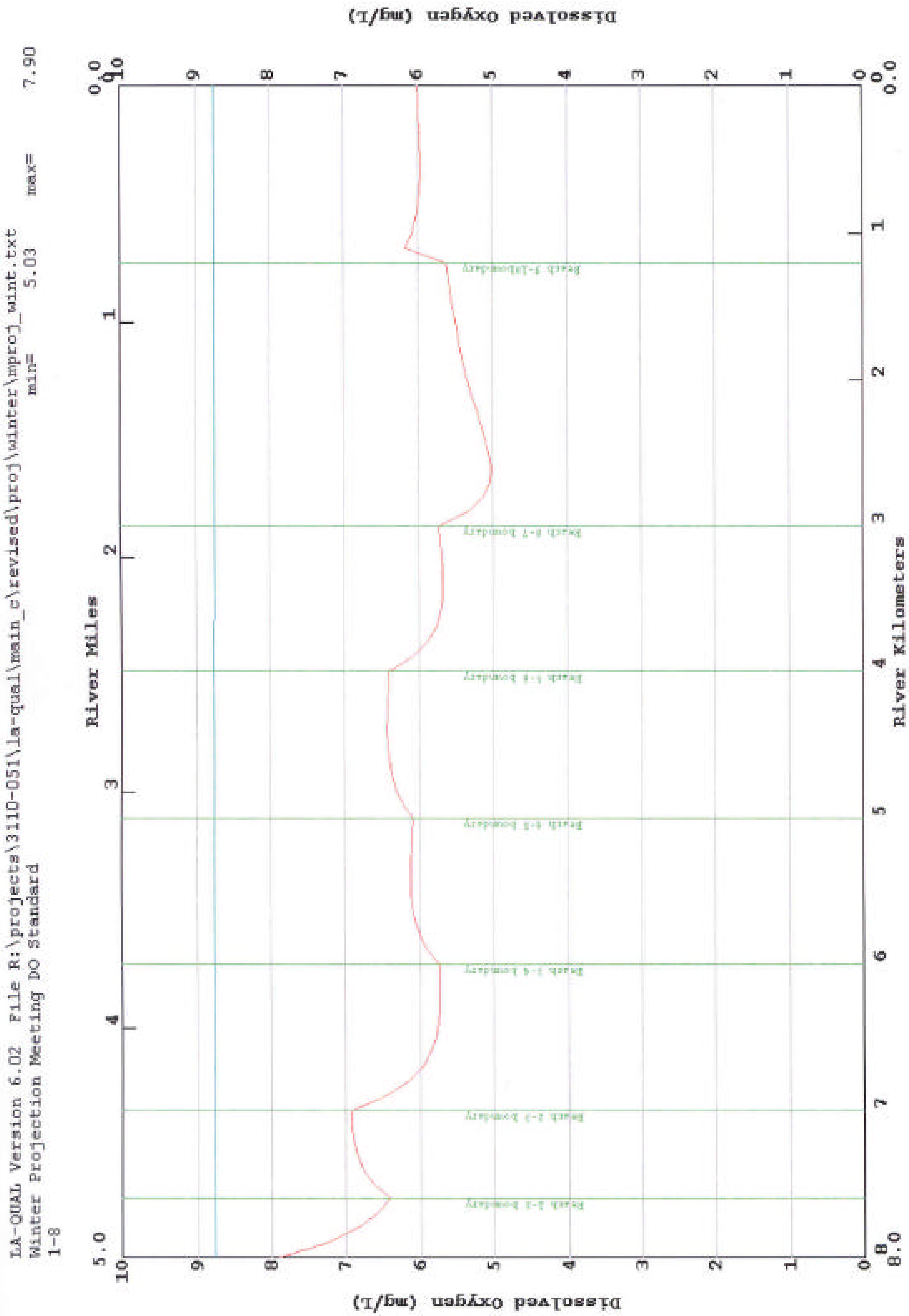

Figure 5.3. Predicted DO for Main Canal winter projection.

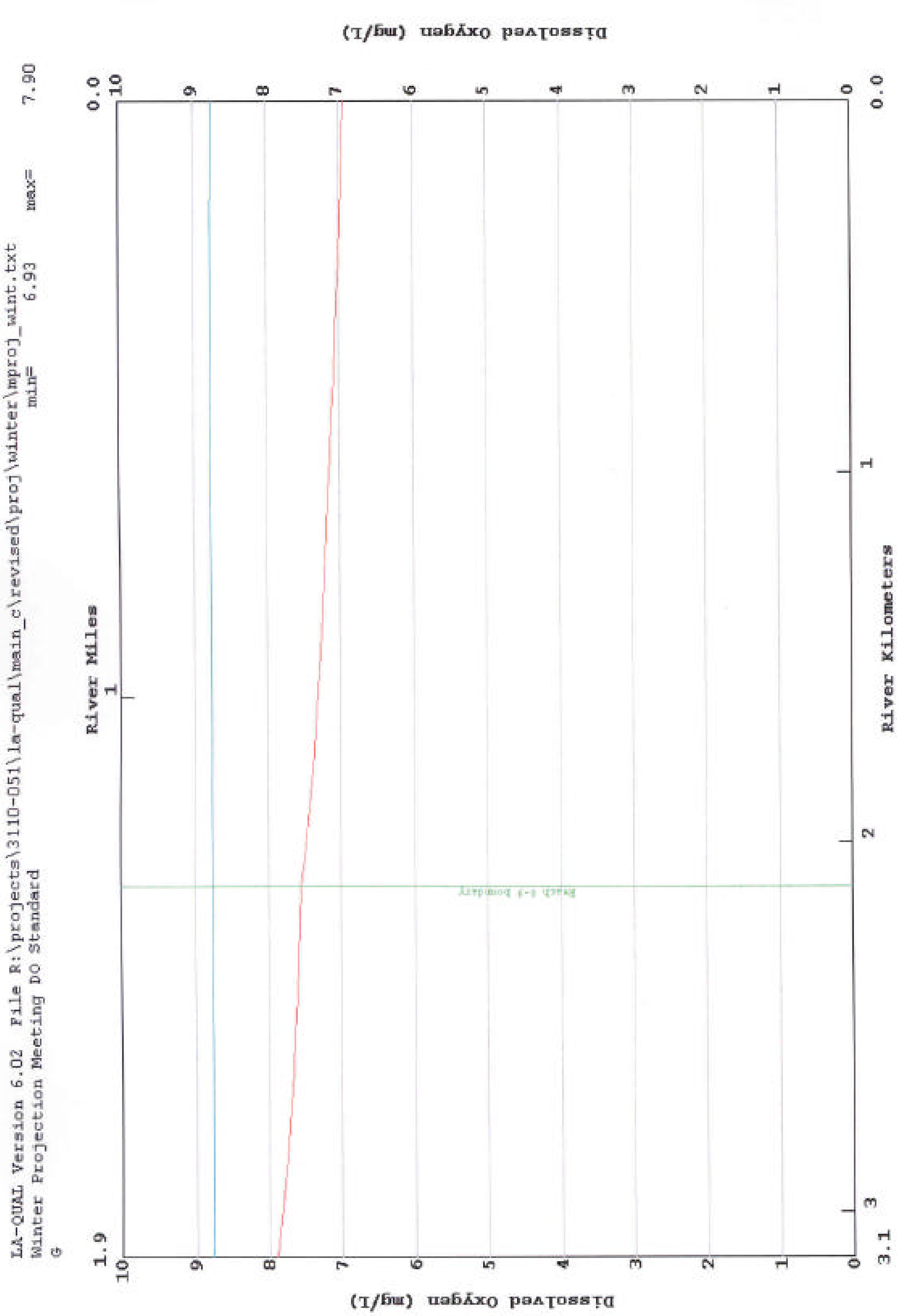

Figure 5.4. Predicted DO for Avondale Gardens Canal winter projection.

Table 5.2. Summary of nonpoint source load reductions required to meet the DO standard.

	Man-made nonpoint sources	Background nonpoint sources
Summer (May – October)	100%	32%
Winter (November – April)	100%	2%

5.4 Calculated TMDL, WLAs, and LAs

5.4.1 Outline of TMDL Calculations

An outline of the TMDL calculations is provided below to assist in understanding the TMDL calculations, which are shown in Appendix O. Slight variances may occur based on individual cases. All of the TMDL calculations were done using the LDEQ TMDL spreadsheet.

A) The natural background benthic loading was estimated from reference stream resuspension (nonpoint CBOD and NBODu) and SOD load data.

B) The calibration man-made benthic loading was determined as follows:

- Calibration resuspension and SOD loads were summed for each reach as g/m^2/day of oxygen demand to get the calibration benthic loading.

- The natural background benthic loading was subtracted from the calibration benthic loading to obtain the man-made calibration benthic loading.

C) Projection benthic loads are determined by trial and error during the modeling process using a uniform percent reduction for resuspension and SOD. Although no point sources were modeled, the design flows of the point sources that were included in the TMDL were increased to obtain an explicit MOS of 20%. Headwater and tributary concentrations of CBODu, NBODu, and DO range from reference stream levels to calibration levels based on the characteristics of the headwater. Where headwaters and tributaries exhibit man-made pollutant loads in excess of reference stream values, the loadings are reduced by the same uniform percent reduction as the benthic loads.

- The projection benthic loading at 20^{o}C is calculated as the sum of the projection resuspension and SOD components expressed as g/m^2/day of oxygen demand.

- The natural background benthic load is subtracted from the projection benthic load to obtain the man-made projection benthic load for each reach.

- The percent reduction of man-made loads for each reach is determined from the difference between the projected man-made nonpoint load and the man-made nonpoint load found during calibration.

- The projection loads are also computed in units of lbs/day and kg/day for each reach.

D) The total stream loading capacity at critical water temperature is calculated as the sum of:

- Headwater and tributary CBODu and NBODu loading in lbs/day and kg/day.

- The natural and man-made projection benthic loading for all reaches of the stream is converted to the loading at critical temperature and summed in lbs/day and kg/day.

- Point source CBODu and NBODu loading in lbs/day and kg/day.

- The margin of safety in lb/day and kg/day.

5.4.2 Results of TMDL Calculations

The TMDL for the biochemical oxygen demanding constituents (CBODu, NBODu, and SOD) was calculated for the summer and winter critical seasons. Printouts of the TMDL spreadsheets are presented in Appendix O. A summary of the loads is presented in Table 5.3.

The nonconservative behavior of dissolved oxygen allows many small or remote point source dischargers to be assimilated by their receiving waterbodies before they reach the modeled waterbody. These dischargers are said to have very little to no impact on the modeled waterbody and therefore, they are not included in the model and are not subject to any reductions based on this TMDL. These facilities are permitted in accordance with state regulation and policies that provide adequate protective controls. New similarly insignificant point sources will continue to be issued permits in this manner. Significant existing point source dischargers are either included in the model or are determined to be insignificant by other modeling. New significant point source dischargers would have to be evaluated individually to determine what impact they have on the impaired waterbody and the appropriate controls.

The point source wasteload allocation (WLA) includes loads from all permitted point sources within the subsegment that are known to discharge oxygen demanding effluent. For this subsegment, none of the point sources were included in the model because they are small and far away from the modeled waterbodies. Their loads were accounted for in the model by calibration as part of the boundary conditions or nonpoint source loading.

The LDEQ TMDL spreadsheet applies a user-specified explicit MOS to the point source loads and to the man-made nonpoint source loads (i.e., all man-made sources). The explicit MOS that was specified in the spreadsheet was 20%. This TMDL required a complete elimination of the man-made nonpoint source loads, thereby eliminating the need for an explicit MOS for that portion of the load.

It should be noted that the 20% explicit MOS used for the point sources accounts for future growth as well as uncertainties associated with the modeling process. The TMDL also includes an implicit MOS created by conservative assumptions in the modeling (see Section 5.1).

Table 5.3. TMDL for subsegment 020501 (sum of CBODu, NBODu, and SOD).

	Load (kg/day) for:	
	Summer (May-Oct)	**Winter (Nov-Apr)**
Point Source WLA	268	268
Point Source Reserve MOS	67	67
Natural Nonpoint Source LA	287	389
Man-made Nonpoint Source LA	0	0
Man-made Nonpoint Source MOS	0	0
TMDL	622	724

6. Sensitivity Analysis

All modeling studies necessarily involve uncertainty and some degree of approximation. It is therefore of value to consider the sensitivity of the model output to changes in model coefficients, and in the hypothesized relationships among the parameters of the model. The LA-QUAL model allows multiple parameters to be varied with a single run. The model adjusts each parameter up or down by the percentage given in the input set. The rest of the parameters listed in the sensitivity section are held at their original value. Thus the sensitivity of each parameter is reviewed separately. A sensitivity analysis was performed on the calibration scenario. Parameters were varied by +/- 30%, except temperature, which was adjusted +/- 2 degrees Centigrade. The results of the sensitivity analysis are summarized in Tables 6.1.

The model was most sensitive to stream reaeration, benthal demand (SOD), stream depth, initial temperature, and incremental flow rate. Due to the long residence time and the location of the minimum DO, the model output was least sensitive to the headwater parameters.

Table 6.1. Summary of calibration model sensitivity analysis.

Parameter	**Negative Parameter Changes**			**Positive Parameter Changes**		
	Parameter Change	**Minimum DO (mg/L)**	**Percentage Difference in DO**	**Parameter Change**	**Minimum DO (mg/L)**	**Percentage Difference in DO**
Stream reaeration	-30%	1.02	-24.4%	30%	1.65	22.2%
Benthal demand (SOD)	-30%	1.67	23.7%	30%	1.14	-15.6%
Stream depth	-30%	1.55	14.8%	30%	1.23	-8.9%
Initial temperature	-2°C	1.49	10.4%	+2°C	1.22	-9.6%
Incremental flow rate	-30%	1.22	-9.6%	30%	1.48	9.6%
Stream velocity	-30%	1.27	-5.9%	30%	1.44	6.7%
CBODu decay rate	-30%	1.39	3.0%	30%	1.32	-2.2%
Incremental DO	-30%	1.31	-3.0%	30%	1.39	3.0%
NBOD decay rate	-30%	1.38	2.2%	30%	1.32	-2.2%
Headwater flow rate	-30%	1.33	-1.5%	30%	1.37	1.5%
Incremental NBODu	-30%	1.37	1.5%	30%	1.33	-1.5%
Headwater CBODu	-30%	1.36	0.7%	30%	1.34	-0.7%
Headwater DO	-30%	1.35	0.0%	30%	1.35	0.0%
Headwater NBODu	-30%	1.35	0.0%	30%	1.35	0.0%

7. Conclusions

In both summer and winter, this TMDL requires a 100% reduction of man-made nonpoint sources. Additionally, background loads would need to be reduced by 32% in the summer and 2% in the winter to maintain a minimum DO of 5.0 mg/L under critical conditions.

This subsegment was listed as impaired due to nutrients as well as organic enrichment / low DO. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants. LDEQ's position, as stated in the declaratory ruling issued by Dale Givens regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the dissolved oxygen criterion is supported, nutrients are also controlled and limited. The implementation of this TMDL through wastewater discharge permits and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources.

This TMDL has been developed to be consistent with the State antidegradation policy (LAC 33:IX.1109.A).

LDEQ will work with other agencies such as local Soil Conservation Districts to implement nonpoint source best management practices in the watershed through the 319 programs. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a four-year cycle. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the four-year cycle. Sampling is conducted on a monthly basis to yield approximately 12 samples per site each year the site is monitored. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, approximately one half of the state's waters are newly assessed for 305(b) and 303(d) listing purposes for each biennial cycle with sampling occurring statewide each year. The four-year cycle follows an initial five-year rotation which covered all basins in the state according to the TMDL priorities.

This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list.

8. References

Bowie, G. L., et. al. 1985. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). EPA/600/3-85/040. Environmental Research Laboratory, US Environmental Protection Agency, Athens, GA: June 1985.

EPA. 1999. Louisiana's 1999 Court Ordered Section 303(d) List. Downloaded from LDEQ website (www.deq.state.la.us/technology/tmdl/303dlist.pdf).

LDEQ 2003a. Louisiana Final 2002 303(d) List. Dated August 20, 2003. Downloaded from LDEQ website (http://www.deq.state.la.us/technology/tmdl/303dlist-2002-final.pdf).

LDEQ. 2003b. Louisiana TMDL Technical Procedures Manual. Revised by R.K. Duerr and M.U. Aguillard. Engineering Group 2, Louisiana Department of Environmental Quality, Baton Rouge, LA: September 22, 2003.

LDEQ. 2003c. Environment Regulatory Code. Part IX. Water Quality Regulations. Chapter 11. Surface Water Quality Standards. § 1123. Numerical Criteria and Designated Uses. Printed from LDEQ website (www.deq.state.la.us/planning/regs/title33/33v09.pdf).

Smythe, E. deEtte. 1999. Overview of the 1995 and 1996 Reference Streams. Prepared for Louisiana Department of Environmental Quality, Baton Rouge, LA: June 28, 1999.

Wiland, B. L. and K. LeBlanc. 2002. LA-QUAL for Windows User's Manual, Model Version 6.02, Manual Revision H. Wiland Consulting, Inc. and Louisiana Department of Environmental Quality. June 25, 2002.